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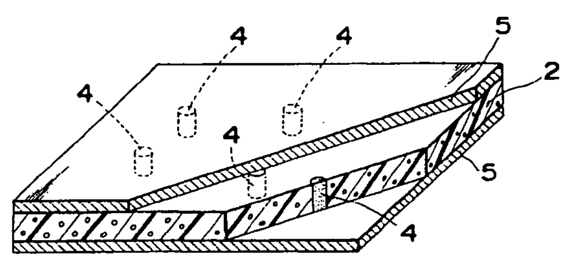
(54) **Method of manufacturing organic substrate used for printed circuits and organic substrate manufactured thereby.**

(57) A method of manufacturing an organic substrate used for printed circuits, which includes the steps of forming through-holes (3) in a porous raw material (2) provided with free tackness films (1) and having compressive shrinkage, filling electro-conductive paste (4) into the through-holes (3), separating the free tackness films (1) from the porous raw material (2) filled with the electro-conductive paste (4) in its through-holes (3), applying metal foils (5) onto the surfaces of the porous raw material (2) from which the free tackness films (1) have been separated, and compressing the porous raw material (2) applied with the metal foils (5) through heating and pressurization, whereby the electro-conductive substances in the electro-conductive paste (4) are connected for electrical connection between the metal foils (5).

Fig. 2



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Secondly, in the conventional arrangements, there are cases where the electro-conductive paste 85 in the amount depending on the thickness of the sheet 81 remains in the state swelling or rising higher than the surface of the insulative substrate 82 as shown in Fig. 10(c). If the second copper foil 86 is applied onto the insulating substrate 82 in the above state, there is no place for the swollen electro-conductive paste 85 to escape, and in some cases, said paste penetrates into a gap between the second copper foil 86 aid the insulating substrate 82 as shown in Fig. 12(a). If the second copper foil 86 for such insulating substrate 82 as referred to above is etched to form the second circuit pattern 87b, a short-circuiting path 85a is formed by the electro-conductive paste 85 which has penetrated into between the second copper foil 86 and the insulating substrate 82 as shown in Fig. 12(b), thus resulting in a short-circuiting fault with respect to near-by circuit patterns.

Due to the problems as described so far, the number of the inner-via-hole connections and circuit pattern density which can be formed per unit area are limited in the conventional organic substrates used for the printed circuits, and therefore, it is difficult to realize a multi-layered circuit board for high density mounting which will be expanded in demand still more henceforth.

SUMMARY OF THE INVENTION

Accordingly, an essential object of the present invention is to provide a method of manufacturing an organic substrate used for printed circuits, which realizes a high performance printed circuit board at a high quality, wherein connecting resistance of electro-conductive paste and that between the electro-conductive paste and metal foils are reduced in the inner-via-hole connection, while maintaining a proper printing aptitude of the electro-conductive paste, with short-circuiting faults between the nearby inner-via-holes being eliminated, and to provide a printed circuit organic substrate produced by said manufacturing method, and also, a multi-layered printed circuit board constituted by said organic substrates.

Another object of the present invention is to provide a manufacturing method of the printed circuit organic substrate, and the organic substrate produced thereby of the above described type which is simple in construction and stable in functioning at high reliability, and can be readily manufactured at low cost.

In accomplishing these and other objects, according to one preferred embodiment of the present invention, there is provided a method of manufacturing an organic substrate used for printed circuits, which includes the steps of forming through-holes in a porous raw material provided with cover films and having compressive shrinkage and composed of a composite material of a non-woven fabric and a thermosetting resin, filling electro-conductive paste into said through-holes, separating the free tackness films from said porous raw material filled with the electro-conductive paste in the through-holes thereof, applying metal foils onto the surface of said porous raw material from which said free tackness films have been separated, and compressing said porous raw material applied with said metal foils through heating and pressurization.

As described above, according to the present invention, by using the porous raw material made of the composite material of the non-woven fabric and thermo-setting resin, the through-holes may be readily filled with the electro-conductive paste comparatively small in the content of the electro-conductive substances, and superior in the aptitude for printing, while, owing to penetration of part of a binder component in the electro-conductive paste into porous portion of the non-woven fabric during the manufacturing process, composition ratio of the electro-conductive substance within the electro-conductive paste is increased.

Moreover, by the employment of the porous raw material having compressive shrinkage and composed of the non-woven fabric and thermo-setting resin, the electro-conductive paste is also compressed in the step in which the porous raw material is compressed through heating and pressurization, and in this case, the binder component is pressed out from between the electro-conductive substances, thereby strengthening binding between the electro-conductive substances, and that between the electro-conductive substances and metal foils for compacting the electro-conductive substances in the electro-conductive paste.

Furthermore, since the binder component of the electro-conductive paste filled in the through-holes is penetrated into the porous raw material side owing to the adoption of said porous raw material having the compressive shrinkage, the amount to be filled may be reduced, and thus the disadvantage that the electro-conductive paste enters between the porous raw material and the metal foils stuck onto the opposite surfaces of said porous raw material, can be eliminated, thereby preventing occurrence of short-circuiting faults between nearby circuit patterns.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become apparent from the following description taken in conjunction with the preferred embodiment thereof with reference to the

and then, held at 200°C for 60 minutes for subsequent lowering down to the room temperature in 30 minutes. By the above step, the electro-conductive paste is also compressed, during which case, the binder component is pressed out from between the electro-conductive substances, and thus, binding between the electro-conductive substances, and between the electro-conductive substances and the metal foils are strengthened for compacting the electro-conductive substances in the electro-conductive paste, while the thickness of the aramid-epoxy sheet 2 is compressed to t2, and the epoxy resin which is one composition of the aramid-epoxy sheet 2, and the electro-conductive paste 4 are cured or hardened. In the above case, the content of the electro-conductive substances in the electro-conductive paste has been raised up to 92.5 wt%.

More specifically, in the present embodiment, when an aramid-epoxy sheet having the thickness t1 in the range of 150 to 220μm, and porosity at 10 to 60% is employed for the aramid-epoxy sheet 2, the thickness t2 thereof after the compressing step by the heating and pressurization as shown in Fig. 1(e) becomes 60 to 200μm, and the porosity is reduced to 0 to 5%, with the size of the void 2a also becoming smaller. When the porosity of the aramid-epoxy sheet 2 is below 10%, the effect in which part of the binder of the electro-conductive paste 4 penetrates into the side of the aramid-epoxy sheet 2 is small, and if it is above 60%, voids remain in the organic substrate.

(Embodiment 2)

Subsequently, referring to Figs. 3(a) to 3(f), a method of manufacturing a printed circuit organic substrate according to a second embodiment of the present invention will be described.

Firstly, an aramid-epoxy sheet 2 similar to that in the first embodiment is prepared as shown in Fig. 3(a), with the thickness of the sheet 2 set to be t3. Then, as shown in Fig. 3(b), the aramid-epoxy sheet 2 is preliminarily compressed through heating and pressurization for 3 minutes at 100°C and 25kgf/cm^2. In this case, the aramid-epoxy sheet 2 is compressed to a thickness of t4, with reduction of the porosity and the size of the void 2a. The purpose of such preliminary compression is to prevent the electro-conductive paste 4 from entering a boundary face between the aramid-epoxy sheet 2 and the metal foils 5 in the subsequent steps by improving adhesion between the free tackness films 1 and the aramid-epoxy sheet 2, and also, to control the amount of the binder in the electro-conductive paste 4 to be penetrated into the side of the aramid-epoxy sheet 2. Then, as shown in Fig. 3(c), through-holes 3 are formed at the predetermined positions in the aramid-epoxy sheet 2 through use of the laser processing, etc. Thereafter, as illustrated in Fig. 3(d), the electro-conductive paste 4 is filled into the through-holes 3. For filling the electro-conductive paste 4, the aramid-epoxy sheet 2 having the through-holes 3 is placed on a table of a printing machine (not shown), and the electro-conductive paste 4 is directly printed from above the free tackness film 1. In this case, the free tackness film 1 on the upper surface plays the parts for a printing mask, and for prevention of soiling on the surface of the aramid-epoxy sheet 2. At this stage, part of the binder in the electro-conductive paste 4 has already been penetrated into the side of said aramid-epoxy sheet 2, and inside the electro-conductive paste 4, composition ratio of the electro-conductive substances with respect to the binder is gradually increasing. Subsequently, the free tackness films 1 are separated from the opposite surfaces of the aramid-epoxy sheet 2. Next, as shown in Fig. 3(e), metal foils 5 such as copper foils, etc. are stuck onto the opposite surfaces of the aramid-epoxy sheet 2. In this state, by heating and pressurization, the aramid-epoxy sheet 2 is compressed, while the aramid-epoxy sheet 2 and the metal foils 5 are bonded to each other as shown in Fig. 3(f). In the above case, conditions for the heating and pressurization are such that temperature is raised from a room temperature up to 200°C in 30 minutes, while applying pressure of 60kgf/cm^2 in vacuum, and then, held at 200°C for 60 minutes for subsequent lowering down to the room temperature in 30 minutes. By the above step, the electro-conductive paste is also compressed, during which case, the binder component is pressed out from between the electro-conductive substances, and thus, binding between the electro-conductive substances, and between the electro-conductive substances and the metal foils is strengthened for compacting the electro-conductive substances in the electro-conductive paste, while the thickness of the aramid-epoxy sheet 2 is compressed to t5, and the epoxy resin which is one composition of the aramid-epoxy sheet 2, and the electro-conductive paste 4 are cured or hardened.

More specifically, in the above embodiment, when an aramid-epoxy sheet having the thickness t3 in the range of 150 to 200μm, and porosity at 40 to 60% is employed for the aramid-epoxy sheet 2, firstly, the thickness t4 thereof after the preliminary compressing step by the heating and pressurization as shown in Fig. 3(b) becomes 100 to 150μm, and the porosity is reduced to 10 to 30%, with the size of the void 2a also becoming smaller. Furthermore, the thickness t5 thereof after the compressing step as shown in Fig. 3(f) becomes 90 to 100μm, and the porosity is reduced to 0 to 5%. with the size of the void 2a also becoming smaller.

the through-holes 3 becomes small in the printed circuit boards for a high density mounting.

Meanwhile, in the first, second or third embodiment, by setting the gel point of the electro-conductive paste 4 to be lower than the softening temperature of the epoxy resin which is one of the compositions of the aramid-epoxy sheet 2, since gelation of the electro-conductive paste is first started in the step for compressing the aramid-epoxy sheet 2 held between the metal foils 5 through heating and pressurization, and after rising of the viscosity thereof to a certain extent, the softening of the epoxy resin as one of the compositions of the sheet 2 is started, the undesirable entry of the electro-conductive paste 4 into the boundary face between the sheet 2 and the metal foils 5 can be prevented. This fact also displays its effect especially when the interval between the through-holes 3 is reduced in the printed circuit board for a high density mounting.

Subsequently, the compression of the porous raw material through heating and pressurization, which plays a particularly important role in the first, second or third embodiment will be explained hereinbelow. The compressibility is represented by a following equation (1),

$$\text{Compressibility} = (T-t)/T \qquad (1)$$

wherein T is the thickness of the porous raw material before heating and pressurization, and t is the thickness of the aramid-epoxy sheet 2 after the heating and pressurization.

In Fig. 5, there is shown a graphical diagram showing relation among pressing pressure for compressing the porous raw material, the compressibility, and the thickness, when the aramid-epoxy sheet of 200μm in thickness, with the porosity of 40% is used for the porous raw material, and the pressurization is effected for 3 minutes at 100°C.

As shown in Fig. 5, although the thickness of the porous raw material is reduced as the pressing pressure increases, the variation of the thickness is reduced when the pressing pressure exceeds a transition point P of the compressibility. The compressibility is obtained by substituting the variation of the thickness for the equation (1).

Accordingly, it is preferable that the preliminary compression to be carried out in the step of Fig. 3-(b) of the second embodiment is effected in a region before reaching the transition point P of the compressibility as shown in Fig. 5, and that the compressions to be conducted in the steps of Fig. 3(f), Fig. 1(e), and Fig. 4(f) are effected in a region after the transition point P of the compressibility.

A graphical diagram of Fig. 6 shows the relation between the compressibility and resistance of the electro-conductive paste filled in the through-holes, with the ordinate representing the resistance value per one through-hole.

The samples used for the measurements in Fig. 6 were prepared in the manner as follows.

In the first place, an aramid-epoxy sheet of 200μm in thickness was used as the porous raw material, and after preliminary compression for 3 minutes at 100°C and 25 kgf/cm^2, the sheet was formed with through-holes each having a diameter of 0.2mm by the use of a laser processing. Then, after electro-conductive paste prepared by dispersing silver powder as the metal particles into a non-solvent type epoxy resin as a binder, was filled in each through-hole, copper foils were stuck onto the opposite surfaces of the aramid-epoxy sheet, which was then processed in such conditions that temperature was raised from a room temperature up to 200°C in 30 minutes, while applying pressure of 60kgf/cm^2 in vacuum, and then, held at 200°C for 60 minutes for subsequent lowering down to the room temperature in 30 minutes. Thereafter, the copper foils at the opposite surfaces of the sheet were etched, and circuit patterns having 500 through-holes connected in series were formed, and by measuring the total resistance of the circuit patterns, the resistance value per one through-hole was calculated.

As shown in Fig. 6, the resistance value was rapidly reduced as the compressibility increases, and when the compressibility exceeded a transition point R of the resistance value, variation of the resistance value was reduced and a stable electrical connection was obtained.

(Embodiment 4)

Referring further to Fig. 7, an organic substrate for the printed circuits according to one embodiment of the present invention will be described hereinbelow.

As shown in Fig. 7, in the printed circuit organic substrate of the present embodiment, the metal foils 5 stuck to the opposite surfaces of the aramid-epoxy sheet 2 are electrically connected by the electro-conductive paste 4 filled in the through-holes 3 provided in said sheet 2. The electro-conductive paste 4 filled in the through-holes 3 is gradually increased in its composition ratio of the electro-conductive substances after the step for filling said paste 4, and in the compression step after bonding of the metal foils 5, the binder component is pressed out from between the electro-conductive substances, thus, the binding between the electro-conductive substances, and also, between the electro-conductive substances and metal foils being strengthened. Consequently, in the electro-conductive paste 4 according to the present embodiment, the electro-conductive substances are

ing the above practice.

In the manufacturing method of the multi-layered circuit boards as described so far, since the electro-conductive paste 30 is sufficiently filled in the state where the under face of each through-hole 29 of the intermediate connecting member 31 is opened, it is possible to inspect the intermediate connecting member 31 as a single member after the step of Fig. 8(g), by using an optical means, etc. Accordingly, in the step of Fig. 8(h), the first circuit board 23, the second circuit board 26 and the intermediate connecting member 31 are to be an laminated in the state where they have been examined, a high manufacturing yield can be maintained to suppress cost increase. On the other hand, in the conventional manufacturing process of the multi-layered circuit board, since the member equivalent to the intermediate connecting member 31 of the present embodiment is formed in the manner as directly laminated on the circuit-board 88 as shown in Figs. 11(a) to 11(d), if any fault occurs at the respective steps, the circuit board 88 which is a good product must be discarded simultaneously, thus resulting in a cost increase.

Furthermore, in the multi-layered circuit board produced by the manufacturing method of the present invention as described so far, since the first and second circuit boards 23 and 26 are connected to each other by the use of the intermediate connecting member 31 to be compressed by the heating and pressurization and the electro-conductive substances in the electro-conductive paste 30 is compacted, while the contact between the electro-conductive substances and the circuit patterns 22 and 25 is improved, the resistance during the inner-via-hole connection is remarkably reduced, and therefore, upon application thereof to the circuit board at high density or multi-layered in which the number of the inner-via-hole connections is increased, the effect as described above becomes still more conspicuous.

As is clear from the foregoing description, according to the present invention, the method of manufacturing the organic substrate used for printed circuit includes the steps of forming through-holes in the porous raw material provided with the free tackness films and having compressive shrinkage, filling the electro-conductive paste into said through-holes, applying the metal foils onto the surface of said porous raw material from which said free tackness films have been separated, and compressing said porous raw material applied with said metal foils by heating and pressurization, and therefore, the method of manufacturing the organic substrate used for printed circuits having a reliable inner-via-hole connection at a low resistance, and the organic substrate manufactured thereby can be realized.

More specifically, according to the present invention, since the electro-conductive paste can be readily filled into the through-holes by using the paste comparatively small in the content of electro-conductive material and superior in the aptitude for printing, and moreover, part to the binder component in the electro-conductive paste is penetrated into the voids of the porous raw material in the manufacturing process, with the composition ratio of the electro-conductive substances int eh electro-conductive paste being increased, the inner-via-hole-connection at low resistance can be realized.

Moreover, in the step of heating and pressurizing the porous raw material after application of the metal foils, the electro-conductive paste is also metal foils, the electro-conductive paste is also compressed, and in this case, the binder component is pressed out from between the electro-conductive substances, and the binding between the electro-conductive substances, and between the electro-conductive substances and the metal foils is strengthened, thereby compacting the electro-conductive substances in the electro-conductive paste.

Therefore, according to the present invention, the high density circuit board requiring the inner-via-hole connection with through-holes of a very small diameter, the high multi-layered circuit board necessitating a large number of inner-via-hole connections, the circuit board for low noise or for high frequency in which low circuit impedance is required, etc. can be readily realized.

Although the present invention has been fully described by way of example with reference to the accompanying drawings, it is to be noted here that various changes and modifications will be apparent to those skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present invention, they should be construed as included therein.

Claims

1. A method of manufacturing an organic substrate used for printed circuits, which comprises the steps of forming through-holes (3) in a porous raw material (2) provided with free tackness films (1) and having compressive shrinkage, filling electro-conductive paste (4) into said through-holes (3), separating the free tackness films (1) from said porous raw material (2) filled with the electro-conductive paste (4) in the through-holes (3) thereof, applying metal foils (5) onto the surfaces of said porous raw material (2) from which said free tackness films (1) have been separated, and compressing said porous raw material (2) applied with said metal foils (5) through heating and pres-

which said free tackness film (1) have been separated, and compressing said porous raw material (2) applied with said metal foils (5) through heating sand pressurisation so as to make more compact, the electro-conductive material in said electro-conductive paste (4),

producing an intermediate connecting member by forming through-holes in the porous raw material and filling electro-conductive paste into said through-holes,

applying said intermediate connecting member on said circuit board, and heating and pressurizing after applying other metal foils thereon, and

forming circuit patterns by processing said other metal foils.

12. An organic substrate used for printed circuits, which comprises a porous raw material (2), electro-conductive paste (4) filled in through-holes (3) formed in said porous raw material (2), and metal foils applied onto opposite surfaces of said porous raw material (2), said metal foils (5) stuck to the opposite surfaces of said porous raw material (2) being electrically connected to each other through the electro-conductive paste by compressing said porous raw material (2) applied with said metal foils (5) through heating and pressurization.

13. An organic substrate used for printed circuits, which comprises a porous raw material (2), electro-conductive paste (4) filled in through-holes (3) formed in said porous raw material (2) and increased in a composition ratio of electro-conductive substances to a binder in said paste, and metal foils applied onto opposite surfaces of said porous raw material (2), said metal foils (5) stuck to the opposite surfaces of said porous raw material (2) being electrically connected to each other through the electro-conductive paste by compressing said porous raw material (2) applied with said metal foils (5) through heating and pressurization.

14. An organic substrate as claimed in Claim 12 or 13, wherein said porous raw material (2) is one compressed through heating and pressurization at compressibility in the range of 10 to 60%.

15. An organic substrate as claimed in Claim 12 or 13, wherein said porous raw material (2) is one preliminarily compressed before filling the electro-conductive paste (4) into said through-holes (3).

16. An organic substrate as claimed in Claim 12 or 13, wherein said porous raw material (2) is mainly composed of an organic material, and has a porosity in the range of 10 to 60%.

17. An organic substrate as claimed in Claim 12 or 13, wherein said porous raw material (2) is of a composite material of a non-wofen fabric made of aromatic polyamide fibers and a thermosetting resin.

18. An organic substrate as claimed in Claim 12 or 13, wherein the electro-conductive substance in the electro-conductive paste (4) is a substance selected from the group consisting of silver, gold, silver palladium, copper and more than one kind of alloys thereof.

19. An organic substrate as claimed in Claim 12 or 13, wherein the porous raw material (2) is one heated and pressurized in a first step for increasing viscosity of the electro-conductive paste (4), and a second step for bonding the metal foils (5) to said porous raw material (2).

20. An organic substrate as claimed in Claim 12 or 13, wherein the electro-conductive paste (4) has a gel point lower than a softening temperature of the resin constituting said porous raw material (2).

21. A multi-layered circuit board which comprises at least a pair of circuit substrates each including circuit patterns formed on opposite surfaces of the organic substrate for the printed circuits as claimed in Claim 12 or 13, and an intermediate connecting member including electro-conductive paste filled in through-holes formed in a porous raw material, said intermediate connecting member being held between said circuit substrates, whereby circuit patterns of said confronting circuit substrates being electrically connected to each other through the electro-conductive paste of said intermediate connecting member by heating and pressurization.

22. A multi-layered circuit board which comprises circuit substrates each including circuit patterns formed on opposite surfaces of the organic substrate for the printed circuits as claimed in Claim 12 or 13, an intermediate connecting member including electro-conductive paste filled in through-holes formed in a porous raw material, and stuck onto said circuit substrate, and metal foils applied on said intermediate connecting member, and formed with circuit patterns after compression through

Fig. 1

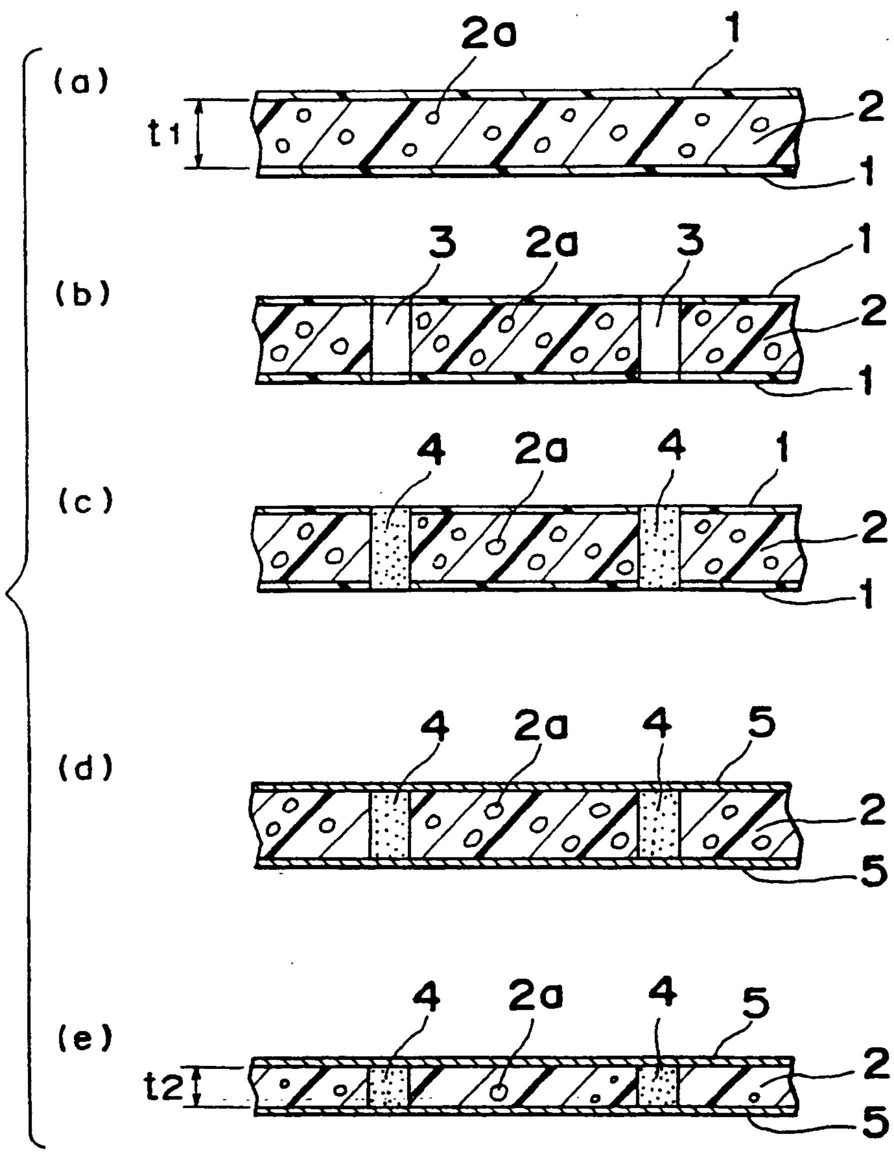
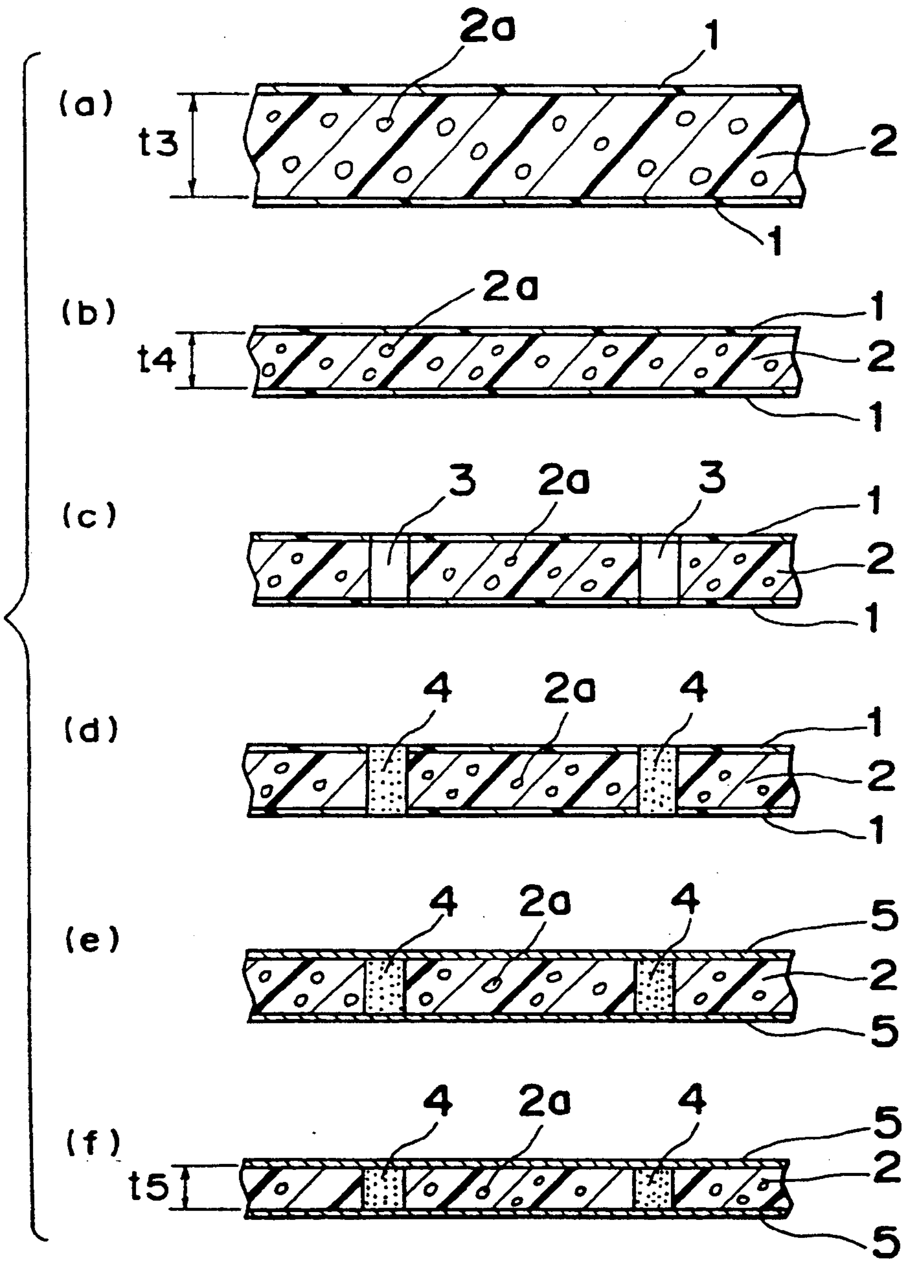


Fig. 3


(a)
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(b)
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t4
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(d)
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t5
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Fig. 5

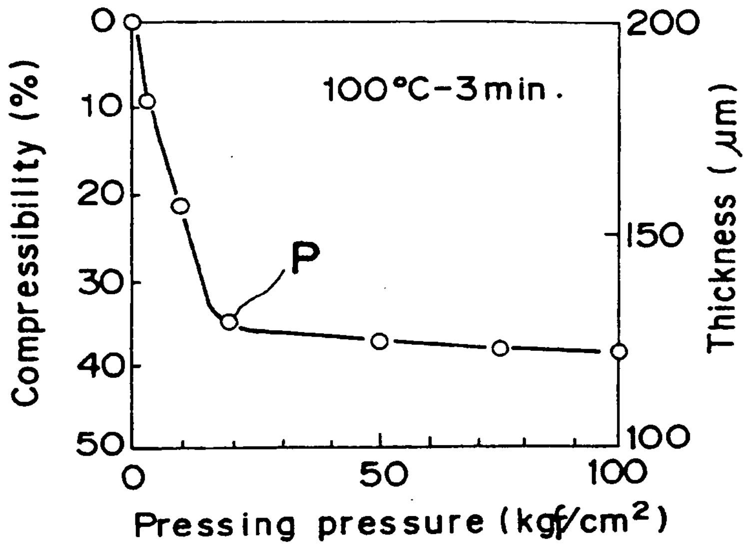

Fig. 6

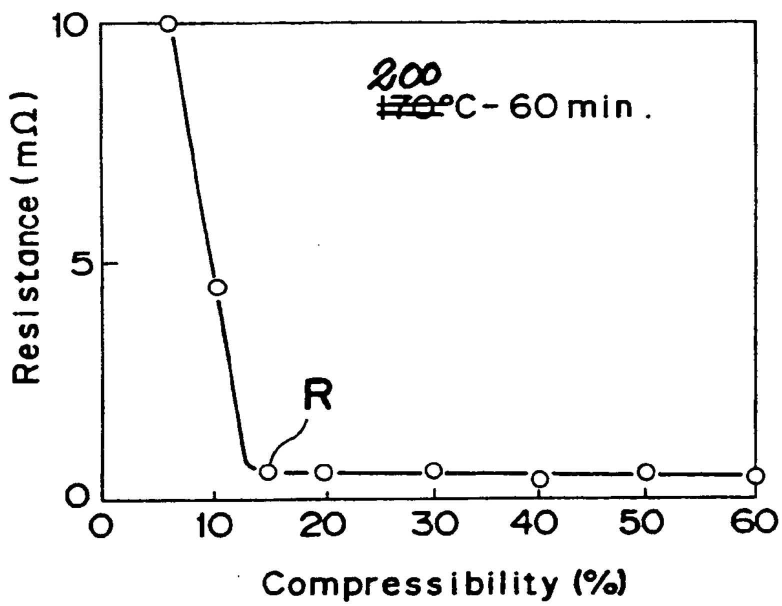

Fig. 7

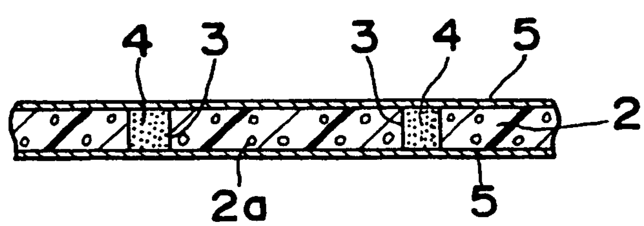

Fig. 9

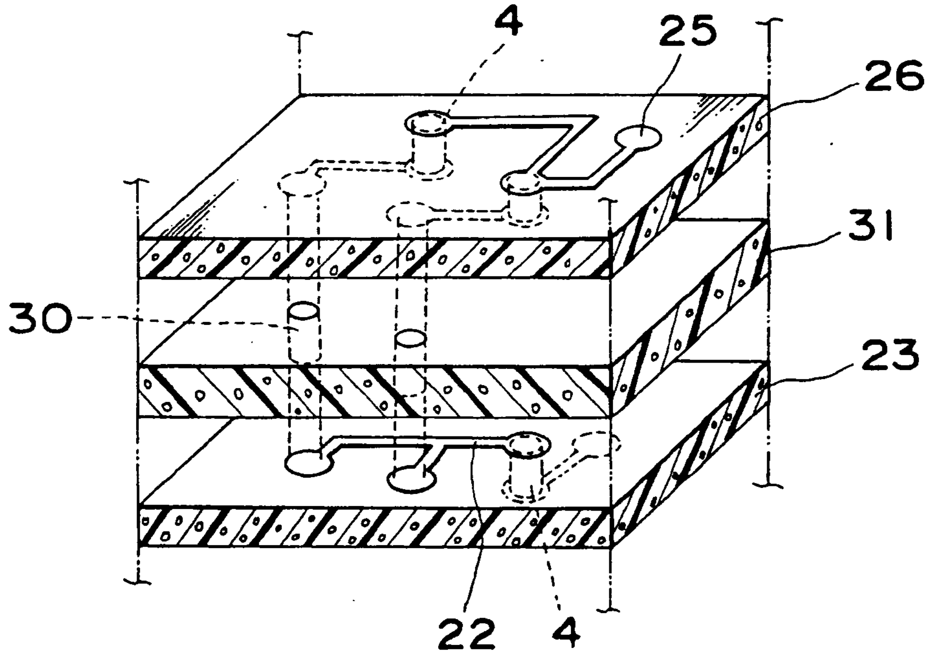

Fig. 11 PRIOR ART